CLAIMS

What is claimed is:

1. A photovoltaic device, comprising:

a first electrode layer;

a second electrode layer; and

a first photoactive layer disposed between the first and second electrode layers, wherein the photoactive layer is disposed in at least partial electrical contact with the first electrode along a first plane, and in at least partial electrical contact with the second electrode along a second plane, and wherein the photoactive layer comprises material that exhibits a type II band offset energy profile, and comprises a first population of nanostructures each having at least one elongated section oriented predominantly normal to at least the first plane.

2. The photovoltaic device of claim **1**, wherein the nanostructures comprise branched nanocrystals having more than one elongated segment.

3. The photovoltaic device of claim **2**, wherein the branched nanocrystals comprise four elongated segments connected at a common apex, and arranged in a substantially tetrahedral geometry.

4. The photovoltaic device of claim **1**, wherein the nanostructures comprise at least a portion that is comprised of a semiconductor selected from Group II-VI, Group III-V or Group IV semiconductors or alloys thereof.

5. The photovoltaic device of claim **1**, wherein the population of nanostructures comprises nanocrystals that comprise one or more of: CdSe, CdTe, InP, InAs, CdS, ZnS, ZnSe, ZnTe, HgTe, GaN, GaP, GaAs, GaSb, InSb, Si, Ge, AlAs, AlSb, PbSe, PbS, or PbTe.

6. The photovoltaic device of claim **1**, wherein the nanostructures comprise nanocrystals.

7. The photovoltaic device of claim **1**, wherein the nanostructures comprise nanowires.

8. The photovoltaic device of claim **1**, wherein the nanostructures comprise: a single-crystal nanostructure, a double-crystal nanostructure, a polycrystalline nanostructure, or an amorphous nanostructure.

9. The photovoltaic device of claim **1**, wherein the population of nanostructures comprises nanocrystals that comprise a core of a first semiconductor material and a shell of a second

semiconductor material, which second semiconductor material is different from the first semiconductor material.

10. The photovoltaic device of claim **9**, wherein the first and second semiconductor materials comprise a type-II band offset profile.

11. The photovoltaic device of claim **10**, wherein the core comprises CdSe and the shell comprises CdTe.

12. The photovoltaic device of claim **10**, wherein the core comprises InP and the shell comprises GaAs.

13. The photovoltaic device of claim **1**, wherein the photoactive layer comprises nanocrystals disposed in a conductive polymer matrix, and wherein the nanocrystals are coupled to the polymer matrix.

14. The photovoltaic device of claim **13**, wherein the nanocrystals are coupled to the polymer matrix via a covalent chemical linkage.

15. The photovoltaic device of claim **14**, wherein the chemical linkage comprises a ligand coupled at a first position to an outer surface of the nanocrystal and at a second position to the polymer matrix.

16. The photovoltaic device of claim **13**, wherein the nanocrystals are electrically coupled to the polymer matrix.

17. The photovoltaic device of claim **1**, wherein the population of nanostructures is predominantly positioned closer to the first electrode than to the second electrode.

18. The photovoltaic device of claim **1**, wherein the photoactive layer comprises nanocrystals disposed in a matrix comprising a small molecule.

19. The photovoltaic device of claim **18**, wherein the small molecule comprises a semiconductive, organic, nonpolymeric molecule.

20. The photovoltaic device of claim **18**, wherein the small molecule has a molecular weight less than 3000, less than 2000, less than 1500, less than 1000, or less than 500.

21. The photovoltaic device of claim **1**, further comprising a hole or electron blocking layer disposed between the photoactive layer and the first or second electrode.

22. The photovoltaic device of claim **1**, further comprising a hole blocking layer disposed between the photoactive layer and the first electrode and an electron blocking layer disposed between the photoactive layer and the second electrode.

23. The photovoltaic device of claim **1**, wherein at least one of the first and second electrodes are flexible.

24. The photovoltaic device of claim **23**, wherein the first and second electrodes and the photoactive layers are flexible.

25. The photovoltaic device of claim **1**, wherein at least one of the first and second electrodes comprises a transparent conductive layer.

26. The photovoltaic device of claim **1**, wherein the device comprises a transparent support layer at least partially covering the first or second electrode, or at least partially covering the photoactive layer, or at least partially covering a combination thereof.

27. The photovoltaic device of claim **1**, wherein at least one of the electrodes comprises aluminum.

28. The photovoltaic device of claim **1**, wherein the photoactive layer is hermetically sealed.

29. The photovoltaic device of claim **28**, the device comprising at least one sealing layer in addition to the first and second electrodes.

30. The photovoltaic device of claim **29**, wherein the device comprises at least first and second sealing layers, the photoactive layer and first and second electrodes being sandwiched between the first and second sealing layers.

31. The photovoltaic device of claim **1**, wherein the overall device comprises a non-planar architecture.

32. The photovoltaic device of claim **1**, wherein the device comprises a convex architecture.

33. The photovoltaic device of claim **1**, wherein the first electrode layer, the photoactive layer and the second electrode layer are oriented in a coiled architecture.

34. The photovoltaic device of claim **1**, wherein the first electrode layer, the photoactive layer and the second electrode layer are oriented in a reciprocating stacked architecture.

35. The photovoltaic device of claim **1**, wherein the population of nanostructures in the photoactive layer comprises at least two different nanocrystal subpopulations, each nanocrystal subpopulation having a different absorption spectrum.

36. The photovoltaic device of claim **35**, wherein the different nanocrystal subpopulations comprise different compositions.

37. The photovoltaic device of claim **35**, wherein the different nanocrystal subpopulations comprise nanocrystals having different size distributions.

38. The photovoltaic device of claim **1**, wherein the nanostructures in the photoactive layer collectively comprise at least two inorganic materials.

39. The photovoltaic device of claim **1**, wherein the nanostructures in the photoactive layer collectively comprise at least two inorganic materials, wherein the nanostructures comprise a core of a first inorganic material and a shell of a second inorganic material.

40. The photovoltaic device of claim **1**, wherein the photoactive layer comprises at least two types of nanocrystals.

41. The photovoltaic device of claim **1**, wherein the photoactive layer comprises fused, partially fused, and/or sintered nanocrystals.

42. The photovoltaic device of claim **1**, wherein the cores of at least two adjacent nanostructures in the photoactive layer are in at least partial electrical contact, and wherein the shells of the at least two adjacent nanostructures, or at least two additional nanostructures, are in at least partial direct electrical contact.

43. The photovoltaic device of claim **1**, wherein the photoactive layer comprises at least two active sublayers.

44. The photovoltaic device of claim **1**, wherein the photoactive layer comprises at least two active sublayers, wherein each of the active sublayers comprises a plurality of nanocrystals of at least one nanocrystal type.

45. The photovoltaic device of claim **1**, wherein the photoactive layer comprises at least two sublayers, wherein at least one of the at least two sublayers comprises an n-type sublayer and at least one of the two sublayers comprises a p-type sublayer.

46. The photovoltaic device of claim **1**, wherein the photoactive layer comprises at least two sublayers, wherein at least one of the at least two sublayers comprises an n-type sublayer and at least one of the two sublayers comprises a p-type sublayer, wherein the photoactive layer comprises a junction between the p-type sublayer and the n-type sublayer.

47. The photovoltaic device of claim **1**, wherein the photoactive layer comprises at least one sublayer comprising a blend of p and n nanocrystals.

48. The photovoltaic device of claim **1**, wherein the photoactive layer comprises at least two active sublayers, at least one of the sublayers comprising the population of nanostructures and at least one of the sublayers comprising a small molecule.

49. The photovoltaic device of claim **48**, wherein the small molecule comprises a semiconductive, organic, nonpolymeric molecule.

50. The photovoltaic device of claim **48**, wherein the small molecule has a molecular weight less than 3000, less than 2000, less than 1500, less than 1000, or less than 500.

51. The photovoltaic device of claim **1**, wherein the device comprises at least a second photoactive layer.

52. The photovoltaic device of claim **1**, further comprising:

a third electrode layer;

a fourth electrode layer; and

a second photoactive layer disposed between the third and fourth electrode layers, wherein the second photoactive layer is disposed in at least partial electrical contact with the third electrode along a third plane, and in at least partial electrical contact with the fourth electrode along a fourth plane, and wherein the second photoactive layer exhibits a type II band offset energy profile, and comprises a second population of nanostructures each having at least one elongated section oriented predominantly normal to at least the third plane, and having a different absorption spectrum from the first population of nanostructures, wherein the third electrode layer, fourth electrode layer and second photoactive layer are attached to, but

electrically insulated from, the first electrode layer, second electrode layer and first photoactive layer.

53. The photovoltaic device of claim **1**, comprising:

a third electrode layer; and,

a second photoactive layer disposed between the second and third electrode layers, wherein the second photoactive layer is disposed in at least partial electrical contact with the second electrode and in at least partial electrical contact with the third electrode.

54. The photovoltaic device of claim **1**, comprising:

a second photoactive layer; and,

a first recombination material disposed between the first and second photoactive layers, wherein the first recombination material is in at least partial electrical contact with the first and second photoactive layers.

55. A photovoltaic device, comprising:

a first electrode layer;

a second electrode layer; and,

a first photoactive layer disposed between the first and second electrode layers, wherein the photoactive layer is disposed in at least partial electrical contact with the first electrode along a first plane and in at least partial electrical contact with the second electrode along a second plane, wherein the photoactive layer comprises a first inorganic material and a second inorganic material different from the first inorganic material, which first and second inorganic materials exhibit a type II band offset energy profile, and wherein the photoactive layer comprises a first population of nanostructures, which nanostructures comprise the first inorganic material, the second inorganic material, or a combination thereof.

56. The photovoltaic device of claim **55**, wherein the nanostructures comprise nanocrystals.

57. The photovoltaic device of claim **55**, wherein the nanostructures comprise nanowires.

58. The photovoltaic device of claim **55**, wherein the nanostructures comprise: a single-crystal nanostructure, a double-crystal nanostructure, a polycrystalline nanostructure, or an amorphous nanostructure.

59. The photovoltaic device of claim **55**, wherein the first inorganic material is a semiconductor and wherein the second inorganic material is a semiconductor.

60. The photovoltaic device of claim **55**, wherein the first inorganic material comprises a first semiconductor selected from the group consisting of: a Group II-VI semiconductor, a Group III-V semiconductor, a Group IV semiconductor, and an alloy thereof, and wherein the second inorganic material comprises a second semiconductor, different from the first semiconductor, selected from the group consisting of: a Group II-VI semiconductor, a Group III-V semiconductor, a Group IV semiconductor, and an alloy thereof.

61. The photovoltaic device of claim **55**, wherein the first population of nanostructures comprises nanocrystals that comprise a core of the first inorganic material and a shell of the second inorganic material.

62. The photovoltaic device of claim **61**, wherein the core comprises CdSe and the shell comprises CdTe.

63. The photovoltaic device of claim **61**, wherein the core comprises InP and the shell comprises GaAs.

64. The photovoltaic device of claim **61**, wherein the nanocrystals are fused, partially fused, and/or sintered.

65. The photovoltaic device of claim **61**, wherein the cores of at least two adjacent nanocrystals are in at least partial direct electrical contact and wherein the shells of at least two adjacent nanocrystals are in at least partial direct electrical contact.

66. The photovoltaic device of claim **61**, wherein the cores of one or more nanocrystals are in at least partial direct electrical contact with the first electrode or the second electrode.

67. The photovoltaic device of claim **55**, wherein the first population of nanostructures comprises nanocrystals comprising the first inorganic material, and wherein the photoactive layer further comprises a second population of nanocrystals comprising nanocrystals which comprise the second inorganic material.

68. The photovoltaic device of claim **67**, wherein the first inorganic material comprises CdSe and the second inorganic material comprises CdTe, the first inorganic material comprises CdS and the second inorganic material comprises CdTe, or the first inorganic material comprises CdS and the second inorganic material comprises ZnSe.

69. The photovoltaic device of claim **67**, wherein adjacent nanocrystals are in at least partial direct electrical contact with each other.

70. The photovoltaic device of claim **67**, wherein the nanocrystals of the first population and the nanocrystals of the second population are intermixed in the photoactive layer.

71. The photovoltaic device of claim **67**, wherein the photoactive layer comprises at least a first sublayer and a second sublayer, wherein the first sublayer comprises the first population of nanocrystals and the second sublayer comprises the second population of nanocrystals.

72. The photovoltaic device of claim **67**, wherein the nanocrystals of the first and/or second populations are fused, partially fused, and/or sintered.

73. The photovoltaic device of claim **55**, wherein the photoactive layer comprises at least two active sublayers.

74. The photovoltaic device of claim **55**, wherein the photoactive layer comprises at least two active sublayers, wherein each of the active sublayers comprises a plurality of nanocrystals of at least one nanocrystal type.

75. The photovoltaic device of claim **55**, wherein the photoactive layer comprises at least two sublayers, wherein at least one of the at least two sublayers comprises an n-type sublayer and at least one of the two sublayers comprises a p-type sublayer.

76. The photovoltaic device of claim **55**, wherein the photoactive layer comprises at least two sublayers, wherein at least one of the at least two sublayers comprises an n-type sublayer and at least one of the two sublayers comprises a p-type sublayer, wherein the photoactive layer comprises a junction between the p-type sublayer and the n-type sublayer.

77. The photovoltaic device of claim **55**, wherein the photoactive layer comprises at least one sublayer comprising a blend of p and n nanocrystals.

78. The photovoltaic device of claim **55**, wherein the photoactive layer further comprises a conductive polymer.

79. The photovoltaic device of claim **55**, wherein the photoactive layer is substantially free of conductive polymer.

80. The photovoltaic device of claim **55**, wherein the photoactive layer further comprises a nonconductive polymer.

81. The photovoltaic device of claim **55**, wherein the nanostructures of the first population each has at least one elongated section oriented predominantly normal to at least the first plane.

82. The photovoltaic device of claim **55**, wherein the nanostructures comprise branched nanocrystals having more than one elongated segment.

83. The photovoltaic device of claim **82**, wherein the branched nanocrystals comprise four elongated segments connected at a common apex, and arranged in a substantially tetrahedral geometry.

84. The photovoltaic device of claim **55**, further comprising a hole or electron blocking layer disposed between the photoactive layer and the first or second electrode.

85. The photovoltaic device of claim **55**, further comprising a hole blocking layer disposed between the photoactive layer and the first electrode and an electron blocking layer disposed between the photoactive layer and the second electrode.

86. The photovoltaic device of claim **55**, wherein at least one of the first and second electrodes are flexible.

87. The photovoltaic device of claim **86**, wherein the first and second electrodes and the photoactive layers are flexible.

88. The photovoltaic device of claim **55**, wherein at least one of the first and second electrodes comprises a transparent conductive layer.

89. The photovoltaic device of claim **55**, wherein at least one of the electrodes comprises aluminum.

90. The photovoltaic device of claim **55**, wherein the photoactive layer is hermetically sealed.

91. The photovoltaic device of claim **90**, the device comprising at least one sealing layer in addition to the first and second electrodes.

92. The photovoltaic device of claim **91**, wherein the device comprises at least first and second sealing layers, the photoactive layer and first and second electrodes being sandwiched between the first and second sealing layers.

93. The photovoltaic device of claim **55**, wherein the overall device comprises a non-planar architecture.

94. The photovoltaic device of claim **55**, wherein the device comprises a convex architecture.

95. The photovoltaic device of claim **55**, wherein the first electrode layer, the photoactive layer and the second electrode layer are oriented in a coiled architecture.

96. The photovoltaic device of claim **55**, wherein the first electrode layer, the photoactive layer and the second electrode layer are oriented in a reciprocating stacked architecture.

97. The photovoltaic device of claim **55**, wherein the first population of nanostructures comprises at least two different nanocrystal subpopulations, each nanocrystal subpopulation having a different absorption spectrum.

98. The photovoltaic device of claim **97**, wherein the different nanocrystal subpopulations comprise different compositions.

99. The photovoltaic device of claim **97**, wherein the different nanocrystal subpopulations comprise nanocrystals having different size distributions.

100. The photovoltaic device of claim **55**, wherein the device comprises at least a second photoactive layer.

101. The photovoltaic device of claim **55**, further comprising:

a third electrode layer;

a fourth electrode layer; and,

a second photoactive layer disposed between the third and fourth electrode layers, wherein the second photoactive layer is disposed in at least partial electrical contact with the third electrode along a third plane and in at least partial electrical contact with the fourth electrode along a fourth plane, wherein the second photoactive layer comprises a second population of nanostructures having a different absorption spectrum from the first population of nanostructures, and wherein the third electrode layer, fourth electrode layer and second

photoactive layer are attached to, but electrically insulated from, the first electrode layer, second electrode layer and first photoactive layer.

102. The photovoltaic device of claim **55**, comprising:

a third electrode layer; and,

a second photoactive layer disposed between the second and third electrode layers, wherein the second photoactive layer is disposed in at least partial electrical contact with the second electrode and in at least partial electrical contact with the third electrode.

103. The photovoltaic device of claim **55**, comprising:

a second photoactive layer; and,

a first recombination material disposed between the first and second photoactive layers, wherein the first recombination material is in at least partial electrical contact with the first and second photoactive layers.

104. A photovoltaic device, comprising:

a first electrode layer;

a second electrode layer; and

a first photoactive layer disposed between the first and second electrode layers, wherein the photoactive layer is disposed in at least partial electrical contact with the first electrode and with the second electrode, wherein the photoactive layer comprises a first population of nanostructures and (a) a conductive polymer whose charge carrying properties have been altered by controlled partial oxidation of the polymer and/or (b) a small molecule.

105. The photovoltaic device of claim **104**, wherein the nanostructures and the oxidized conductive polymer of (a) or the small molecule of (b) exhibit a type II band offset energy profile.

106. The photovoltaic device of claim **104**, wherein the small molecule of (b) comprises a semiconductive, organic, nonpolymeric molecule.

107. The photovoltaic device of claim **104**, wherein the small molecule of (b) has a molecular weight less than 3000, less than 2000, less than 1500, less than 1000, or less than 500.

108. The photovoltaic device of claim **104**, wherein the small molecule of (b) conducts holes.

109. The photovoltaic device of claim **104**, wherein the nanostructures are disposed in a matrix comprising the oxidized conductive polymer of (a) or the small molecule of (b).

110. The photovoltaic device of claim **104**, wherein the photoactive layer comprises at least two sublayers, wherein at least one of the sublayers comprises the nanostructures and at least one of the sublayers comprises the oxidized conductive polymer of (a) or the small molecule of (b).

111. The photovoltaic device of claim **104**, wherein the photoactive layer comprises the small molecule of (b) dispersed in a polymer.

112. The photovoltaic device of claim **111**, wherein the polymer is a conductive polymer.

113. The photovoltaic device of claim **104**, wherein the nanostructures comprise nanocrystals.

114. The photovoltaic device of claim **104**, wherein the nanostructures comprise nanowires.

115. The photovoltaic device of claim **104**, wherein the nanostructures comprise: a single-crystal nanostructure, a double-crystal nanostructure, a polycrystalline nanostructure, or an amorphous nanostructure.

116. The photovoltaic device of claim **104**, wherein the nanostructures comprise at least a portion that is comprised of a semiconductor selected from the group consisting of: a Group II-VI semiconductor, a Group III-V semiconductor, a Group IV semiconductor, and an alloy thereof

117. The photovoltaic device of claim **104**, wherein the population of nanostructures comprises nanocrystals that comprise one or more of: CdSe, CdTe, InP, InAs, CdS, ZnS, ZnSe, ZnTe, HgTe, GaN, GaP, GaAs, GaSb, InSb, Si, Ge, AlAs, AlSb, PbSe, PbS, or PbTe.

118. The photovoltaic device of claim **104**, wherein the photoactive layer is disposed in at least partial electrical contact with the first electrode along a first plane and with the second electrode along a second plane.

119. The photovoltaic device of claim **118**, wherein the nanostructures of the first population each has at least one elongated section oriented predominantly normal to at least the first plane.

120. The photovoltaic device of claim **104**, wherein the nanostructures comprise branched nanocrystals having more than one elongated segment.

121. The photovoltaic device of claim **104**, further comprising a hole or electron blocking layer disposed between the photoactive layer and the first or second electrode.

122. The photovoltaic device of claim **104**, further comprising a hole blocking layer disposed between the photoactive layer and the first electrode and an electron blocking layer disposed between the photoactive layer and the second electrode.

123. The photovoltaic device of claim **104**, wherein at least one of the first and second electrodes are flexible.

124. The photovoltaic device of claim **123**, wherein the first and second electrodes and the photoactive layers are flexible.

125. The photovoltaic device of claim **104**, wherein at least one of the first and second electrodes comprises a transparent conductive layer.

126. The photovoltaic device of claim **104**, wherein at least one of the electrodes comprises aluminum.

127. The photovoltaic device of claim **104**, wherein the photoactive layer is hermetically sealed.

128. The photovoltaic device of claim **127**, the device comprising at least one sealing layer in addition to the first and second electrodes.

129. The photovoltaic device of claim **128**, wherein the device comprises at least first and second sealing layers, the photoactive layer and first and second electrodes being sandwiched between the first and second sealing layers.

130. The photovoltaic device of claim **104**, wherein the overall device comprises a non-planar architecture.

131. The photovoltaic device of claim **104**, wherein the device comprises a convex architecture.

132. The photovoltaic device of claim **104**, wherein the first electrode layer, the photoactive layer and the second electrode layer are oriented in a coiled architecture.

133. The photovoltaic device of claim **104**, wherein the first electrode layer, the photoactive layer and the second electrode layer are oriented in a reciprocating stacked architecture.

134. The photovoltaic device of claim **104**, wherein the first population of nanostructures comprises at least two different nanocrystal subpopulations, each nanocrystal subpopulation having a different absorption spectrum.

135. The photovoltaic device of claim **134**, wherein the different nanocrystal subpopulations comprise different compositions.

136. The photovoltaic device of claim **134**, wherein the different nanocrystal subpopulations comprise nanocrystals having different size distributions.

137. The photovoltaic device of claim **104**, wherein the device comprises at least a second photoactive layer.

138. The photovoltaic device of claim **104**, further comprising:

a third electrode layer;

a fourth electrode layer; and,

a second photoactive layer disposed between the third and fourth electrode layers, wherein the second photoactive layer is disposed in at least partial electrical contact with the third electrode along a third plane and in at least partial electrical contact with the fourth electrode along a fourth plane, wherein the second photoactive layer comprises a second population of nanostructures having a different absorption spectrum from the first population of nanostructures, and wherein the third electrode layer, fourth electrode layer and second photoactive layer are attached to, but electrically insulated from, the first electrode layer, second electrode layer and first photoactive layer.

139. The photovoltaic device of claim **104**, comprising:

a third electrode layer; and,

a second photoactive layer disposed between the second and third electrode layers, wherein the second photoactive layer is disposed in at least partial electrical contact with the second electrode and in at least partial electrical contact with the third electrode.

140. The photovoltaic device of claim **104**, comprising:

a second photoactive layer; and,

a first recombination material disposed between the first and second photoactive layers, wherein the first recombination material is in at least partial electrical contact with the first and second photoactive layers.

141. A photovoltaic device, comprising:

a first electrode layer;

a second electrode layer;

a first recombination material disposed between the first and second electrode layers;

a first photoactive layer disposed between the first electrode layer and the first recombination material, wherein the first photoactive layer is disposed in at least partial electrical contact with the first electrode and with the first recombination material, and wherein the first photoactive layer comprises a first population of nanostructures; and,

a second photoactive layer disposed between the first recombination material and the second electrode layer, wherein the second photoactive layer is disposed in at least partial electrical contact with the second electrode and with the first recombination material, and wherein the second photoactive layer comprises a second population of nanostructures.

142. The photovoltaic device of claim **141**, wherein the first and second photoactive layers each comprises a material that exhibits a type II band offset energy profile.

143. The photovoltaic device of claim **141**, wherein the first recombination material comprises a recombination layer disposed between the first and second photoactive layers.

144. The photovoltaic device of claim **141**, wherein the first photoactive layer is disposed in at least partial electrical contact with the first electrode along a first plane and the second photoactive layer is disposed in at least partial electrical contact with the second electrode along a second plane.

145. The photovoltaic device of claim **144**, wherein the nanostructures of the first population each has at least one elongated section oriented predominantly normal to at least the first plane and/or the nanostructures of the second population each has at least one elongated section oriented predominantly normal to at least the second plane.

146. The photovoltaic device of claim **141**, wherein the first photoactive layer comprises a first population of nanocrystals disposed in a conductive polymer matrix and/or the second photoactive layer comprises a second population of nanocrystals disposed in a conductive polymer matrix.

147. The photovoltaic device of claim **146**, wherein the charge carrying properties of the conductive polymer matrix of the first and/or second photoactive layer have been altered by controlled partial oxidation of the polymer.

148. The photovoltaic device of claim **141**, wherein the first photoactive layer comprises a first population of nanocrystals disposed in a matrix comprising a small molecule and/or the second photoactive layer comprises a second population of nanocrystals disposed in a matrix comprising a small molecule.

149. The photovoltaic device of claim **141**, wherein the first photoactive layer comprises a first inorganic material and a second inorganic material different from the first inorganic material, which first and second inorganic materials exhibit a type II band offset energy profile, and wherein the nanostructures of the first population comprise the first inorganic material, the second inorganic material, or a combination thereof, and/or wherein the second photoactive layer comprises a third inorganic material and a fourth inorganic material different from the third inorganic material, which third and fourth inorganic materials exhibit a type II band offset energy profile, and wherein the nanostructures of the second population comprise the third inorganic material, the fourth inorganic material, or a combination thereof.

150. The photovoltaic device of claim **141**, wherein the nanostructures of the first and/or second population comprise at least a portion that is comprised of a semiconductor selected from Group II-VI, Group III-V or Group IV semiconductors or alloys thereof.

151. The photovoltaic device of claim **141**, wherein at least one of the first and second electrodes comprises a transparent conductive layer.

152. The photovoltaic device of claim **141**, wherein the first recombination material comprises a transparent material.

153. The photovoltaic device of claim **141**, wherein the first recombination material comprises a metal, a conductive polymer, and/or a small molecule.

154. The photovoltaic device of claim **153**, wherein the first recombination material comprises aluminum, silver, gold, PEDOT:PSS, TPD, NPD, and/or TAZ.

155. A photovoltaic device, comprising:

a first electrode layer;

a second electrode layer;

a third electrode layer;

a first photoactive layer disposed between the first electrode layer and the second electrode layer, wherein the first photoactive layer is disposed in at least partial electrical contact with the first electrode and with the second electrode, wherein the first photoactive layer comprises a first population of nanostructures; and,

a second photoactive layer disposed between the second electrode layer and the third electrode layer, wherein the second photoactive layer is disposed in at least partial electrical contact with the second electrode and with the third electrode, wherein the second photoactive layer comprises a second population of nanostructures.

156. The photovoltaic device of claim **155**, wherein the first and second photoactive layers each comprises a material that exhibits a type II band offset energy profile.

157. The photovoltaic device of claim **155**, wherein the first photoactive layer is disposed in at least partial electrical contact with the first electrode along a first plane and in at least partial electrical contact with the second electrode along a second plane, and wherein the second photoactive layer is disposed in at least partial electrical contact with the second electrode along a third plane and in at least partial electrical contact with the third electrode along a fourth plane.

158. The photovoltaic device of claim **157**, wherein the nanostructures of the first population each has at least one elongated section oriented predominantly normal to at least the first plane and/or the nanostructures of the second population each has at least one elongated section oriented predominantly normal to at least the third plane.

159. The photovoltaic device of claim **155**, wherein the first photoactive layer comprises a first population of nanocrystals disposed in a conductive polymer matrix and/or the second photoactive layer comprises a second population of nanocrystals disposed in a conductive polymer matrix.

160. The photovoltaic device of claim **159**, wherein the charge carrying properties of the conductive polymer matrix of the first and/or second photoactive layer have been altered by controlled partial oxidation of the polymer.

161. The photovoltaic device of claim **155**, wherein the first photoactive layer comprises a first population of nanocrystals disposed in a matrix comprising a small molecule and/or the second

photoactive layer comprises a second population of nanocrystals disposed in a matrix comprising a small molecule.

162. The photovoltaic device of claim **155**, wherein the first photoactive layer comprises a first inorganic material and a second inorganic material different from the first inorganic material, which first and second inorganic materials exhibit a type II band offset energy profile, and wherein the nanostructures of the first population comprise the first inorganic material, the second inorganic material, or a combination thereof, and/or wherein the second photoactive layer comprises a third inorganic material and a fourth inorganic material different from the third inorganic material, which third and fourth inorganic materials exhibit a type II band offset energy profile, and wherein the nanostructures of the second population comprise the third inorganic material, the fourth inorganic material, or a combination thereof.

163. The photovoltaic device of claim **155**, wherein the nanostructures of the first and/or second population comprise at least a portion that is comprised of a semiconductor selected from Group II-VI, Group III-V or Group IV semiconductors or alloys thereof.

164. The photovoltaic device of claim **155**, wherein at least two of the first, second, and third electrodes comprise a transparent conductive layer.

165. A composition comprising: a first population of nanostructures and a second population of nanostructures, which first population comprises nanostructures comprising a first material, and which second population comprises nanostructures comprising a second material different from the first material.

166. The composition of claim **165**, wherein the nanostructures comprise nanocrystals.

167. The composition of claim **165**, wherein the nanostructures comprise nanowires.

168. The composition of claim **165**, wherein the nanostructures comprise: a single-crystal nanostructure, a double-crystal nanostructure, a polycrystalline nanostructure, or an amorphous nanostructure.

169. The composition of claim **165**, wherein the first material is a first inorganic material and the second material is a second inorganic material.

170. The composition of claim **165**, wherein the first material comprises a first semiconductor and the second material comprises a second semiconductor.

171. The composition of claim **170**, wherein the first material comprises an n-type semiconductor and the second material comprises a p-type semiconductor.

172. The composition of claim **165**, wherein the first and second materials exhibit a type II band offset energy profile.

173. The composition of claim **165**, wherein the first and second materials exhibit a type I band offset energy profile.

174. The composition of claim **165**, wherein adjacent nanostructures are in at least partial direct electrical contact with each other.

175. The composition of claim **165**, wherein the nanostructures of the first population and the nanostructures of the second population are intermixed.

176. A film formed from the composition of claim **165**.

177. The film of claim **176**, wherein the film comprises at least a first sublayer and a second sublayer, wherein the first sublayer comprises the first population of nanostructures and the second sublayer comprises the second population of nanostructures.

178. The film of claim **176**, wherein the film is disposed between two electrode layers.

179. The composition of claim **165**, wherein the nanostructures of the first and/or second populations are fused, partially fused, and/or sintered.

180. The composition of claim **165**, further comprising a conductive polymer.

181. The composition of claim **165**, wherein the composition is substantially free of conductive polymer.

182. The composition of claim **165**, further comprising a nonconductive polymer.

183. A composition, comprising: a first population of nanostructures disposed in a matrix, the matrix comprising (a) a first, conductive polymer whose charge carrying properties have been altered by controlled partial oxidation of the polymer and/or (b) a second polymer and a small molecule.

184. The composition of claim **183**, wherein the small molecule of (b) comprises a semiconductive, organic, nonpolymeric molecule.

185. The composition of claim **183**, wherein the small molecule of (b) has a molecular weight less than 3000, less than 2000, less than 1500, less than 1000, or less than 500.

186. The composition of claim **183**, wherein the second polymer of (b) is a conductive polymer.

187. The composition of claim **183**, wherein the nanostructures comprise nanocrystals.

188. The composition of claim **183**, wherein the nanostructures comprise nanowires.

189. The composition of claim **183**, wherein the nanostructures comprise: a single-crystal nanostructure, a double-crystal nanostructure, a polycrystalline nanostructure, or an amorphous nanostructure.

190. The composition of claim **183**, wherein the nanostructures and the matrix exhibit a type II band offset energy profile.

191. The composition of claim **183**, wherein the nanostructures and the matrix exhibit a type I band offset energy profile.

192. A film formed from the composition of claim **183**.

193. The film of claim **192**, wherein the film is disposed between two electrode layers.

194. A composition, comprising: a first population of nanostructures and a small molecule, each nanostructure of the first population having at least one elongated section oriented predominantly normal to at least a first plane.

195. The composition of claim **194**, wherein the nanostructures comprise branched nanocrystals having more than one elongated segment.

196. The composition of claim **194**, wherein the small molecule comprises a semiconductive, organic, nonpolymeric molecule.

197. The composition of claim **194**, wherein the small molecule has a molecular weight less than 3000, less than 2000, less than 1500, less than 1000, or less than 500.

198. The composition of claim **194**, wherein the nanostructures are disposed in a matrix comprising the small molecule.

199. The composition of claim **198**, wherein the matrix comprises a polymer.

200. The composition of claim **199**, wherein the polymer is a conductive polymer.

201. A film formed from the composition of claim **194**, wherein the first plane is parallel to a surface of the film.

202. A composition, comprising:

a population of nanostructures;

a polymer and/or a small molecule;

a first solvent; and,

a second solvent, wherein the first solvent has a vapor pressure that is not equal to a vapor pressure of the second solvent, and wherein at least one of the first and second solvents is free of chloroform and pyridine.

203. The composition of claim **202**, wherein the nanostructures comprise nanocrystals.

204. The composition of claim **202**, wherein the nanostructures comprise: a single-crystal nanostructure, a double-crystal nanostructure, a polycrystalline nanostructure, or an amorphous nanostructure.

205. The composition of claim **202**, wherein the first solvent and the second solvent have different polarities.

206. The composition of claim **202**, wherein the first solvent and/or the second solvent is selected from the group consisting of: chloroform, toluene, tetrahydrofuran, xylene, and chlorobenzene.

207. The composition of claim **206**, wherein the first solvent is toluene and the second solvent is chloroform.

208. The composition of claim **202**, wherein a ratio of the first solvent to the second solvent is greater than 0.15:0.85 and less than 0.85:0.15 by volume.

209. The composition of claim **208**, wherein a ratio of the first solvent to the second solvent is greater than 0.3:0.7 and less than 0.7:0.3 by volume.

210. The composition of claim **202**, comprising a third solvent.

211. A method of producing a photovoltaic device, comprising:

providing a first planar substrate having a first conductive layer disposed thereon;

coating the first substrate with a photoactive matrix that exhibits a type II band offset energy profile, and comprises at least a first population of elongated semiconductor nanostructures, the nanostructures comprising a longitudinal axis, to provide a photoactive layer;

orienting the semiconductor nanostructures such that their longitudinal axes are predominantly oriented normal to the first planar substrate; and

laminating a second conductive layer onto the photoactive layer.

212. The method of claim **211**, wherein the nanostructures comprise nanocrystals.

213. The method of claim **211**, wherein the nanostructures comprise nanowires.

214. The method of claim **211**, wherein the nanostructures comprise: a single-crystal nanostructure, a double-crystal nanostructure, a polycrystalline nanostructure, or an amorphous nanostructure.

215. The method of claim **211**, further comprising providing a blocking layer on the first substrate prior to coating the first substrate with a photoactive matrix.

216. The method of claim **211**, further comprising providing a blocking layer on the photoactive layer prior to laminating the second conductive layer onto the photoactive layer.

217. The method of claim **216**, further comprising providing one or more sealing layers over opposing surfaces of the photovoltaic device in addition to the first substrate and second conductive layer, whereby the one or more sealing layers hermetically seal the photovoltaic device.

218. A method of producing a photovoltaic device, the method comprising:

providing a first planar substrate having a first conductive layer disposed thereon;

coating the first substrate with a composition that comprises a population of nanostructures, which nanostructures comprise a core of a first material and a shell of a second material different from the first material, to provide a photoactive layer;

fusing, partially fusing, and/or sintering the nanostructures; and

laminating a second conductive layer onto the photoactive layer.

219. The method of claim **218**, wherein the nanostructures comprise nanocrystals.

220. The method of claim **218**, wherein the nanostructures comprise nanowires.

221. The method of claim **218**, wherein the nanostructures comprise: a single-crystal nanostructure, a double-crystal nanostructure, a polycrystalline nanostructure, or an amorphous nanostructure.

222. The method of claim **218**, wherein the first material is a first inorganic material and the second material is a second inorganic material.

223. The method of claim **218**, wherein the first material comprises a first semiconductor and wherein the second material comprises a second semiconductor.

224. The method of claim **218**, further comprising providing a blocking layer on the first substrate prior to coating the first substrate with the composition.

225. The method of claim **218**, further comprising providing a blocking layer on the photoactive layer prior to laminating the second conductive layer onto the photoactive layer.

226. The method of claim **218**, further comprising providing one or more sealing layers over opposing surfaces of the photovoltaic device, whereby the one or more sealing layers hermetically seal the photovoltaic device.

227. A method of producing a layered device comprising a first population of nanostructures and a second population of nanostructures, which first population comprises nanostructures comprising a first material, and which second population comprises nanostructures comprising a second material different from the first material, the method comprising:

providing a first substrate; and,

coating the first substrate with a composition comprising the first population of nanostructures to provide a first layer.

228. The method of claim **227**, wherein the nanostructures of the first and/or second populations comprise nanocrystals.

229. The method of claim **227**, wherein the nanostructures of the first and/or second populations comprise nanowires.

230. The method of claim **227**, wherein the nanostructures of the first and/or second populations comprise: a single-crystal nanostructure, a double-crystal nanostructure, a polycrystalline nanostructure, or an amorphous nanostructure.

231. The method of claim **227**, wherein the first material is a first inorganic material and the second material is a second inorganic material.

232. The method of claim **227**, wherein coating the first substrate with a composition comprising the first population of nanostructures comprises coating the first substrate with a composition comprising a mixture of the first and second populations of nanostructures, providing a first layer in which the nanostructures of the first and second populations are intermixed.

233. The method of claim **227**, further comprising coating the first substrate with a composition comprising the second population of nanostructures, to provide a second layer.

234. The method of claim **227**, wherein the second population of nanostructures is disposed on the first substrate.

235. The method of claim **227**, wherein the first substrate is planar.

236. The method of claim **235**, wherein a first conductive layer is disposed on the first planar substrate.

237. The method of claim **236**, further comprising providing a blocking layer on the first substrate prior to coating the first substrate with the composition comprising the first population of nanostructures.

238. The method of claim **236**, further comprising layering a second conductive layer onto the first layer.

239. The method of claim **238**, further comprising providing a blocking layer on the first layer prior to laminating the second conductive layer onto the first layer.

240. The method of claim **235**, further comprising providing one or more sealing layers over opposing surfaces of the device, whereby the one or more sealing layers hermetically seal the device.

241. A method of producing a photovoltaic device, the method comprising:

providing a first planar substrate having a first conductive layer disposed thereon;

coating the first substrate with a composition that comprises a first population of nanostructures to provide a first photoactive layer;

layering a second conductive layer onto the first photoactive layer;

coating the second conductive layer with a composition that comprises a second population of nanostructures to provide a second photoactive layer; and,

layering a third conductive layer onto the second photoactive layer.

242. A method of producing a photovoltaic device, the method comprising:

providing a first planar substrate having a first conductive layer disposed thereon;

coating the first substrate with a composition that comprises a first population of nanostructures to provide a first photoactive layer;

disposing a first recombination material onto the first photoactive layer;

coating the first recombination material and any exposed portion of the first photoactive layer with a composition that comprises a second population of nanostructures to provide a second photoactive layer; and,

layering a second conductive layer onto the second photoactive layer.

243. The method of claim **242**, wherein disposing the first recombination material onto the first photoactive layer comprises coating the first photoactive layer with the first recombination material to provide a first recombination layer.

244. A method of forming a nanocomposite layer, the method comprising:

providing a planar substrate;

providing a first mixture comprising a population of nanostructures, a polymer and/or a small molecule, a first solvent, and a second solvent, wherein the first solvent has a vapor pressure that is not equal to a vapor pressure of the second solvent, and wherein at least one of the first and second solvents is free of chloroform and pyridine; and,

coating the substrate with the first mixture to provide the nanocomposite layer.

245. The method of claim **244**, wherein coating the substrate comprises permitting the evaporation of at least the majority of the first and second solvents.

246. The method of claim **244**, comprising:

providing the nanostructures in the first solvent;

providing the polymer and/or the small molecule in the second solvent; and,

combining the nanostructures in the first solvent and the polymer and/or small molecule in the second solvent to provide the first mixture.

247. The method of claim **246**, wherein the vapor pressure of the first solvent is lower than the vapor pressure of the second solvent.

248. The method of claim **246**, wherein the vapor pressure of the first solvent is higher than the vapor pressure of the second solvent.

249. The method of claim **246**, wherein the first solvent is less polar than the second solvent.

250. The method of claim **246**, wherein the first solvent and the second solvent are combined in a ratio that results in the nanocomposite layer having a selected morphology.

251. The method of claim **244**, wherein a ratio of the first solvent to the second solvent is greater than 0.15:0.85 and less than 0.85:0.15 by volume.

252. The method of claim **251**, wherein a ratio of the first solvent to the second solvent is greater than 0.3:0.7 and less than 0.7:0.3 by volume.

253. The method of claim **244**, wherein coating the substrate with the first mixture comprises spin coating the first mixture onto the substrate.

254. The method of claim **244**, wherein coating the substrate with the first mixture comprises applying the first mixture to the substrate with a doctor-blade or screen printing, ink-jet printing, dip coating, sheer coating, tape casting, or film casting the first mixture onto the substrate.

255. The method of claim **244**, wherein the nanostructures comprise nanocrystals.

256. The method of claim **244**, wherein the nanostructures comprise: a single-crystal nanostructure, a double-crystal nanostructure, a polycrystalline nanostructure, or an amorphous nanostructure.

257. The method of claim **244**, wherein the first solvent and/or the second solvent is selected from the group consisting of: chloroform, toluene, tetrahydrofuran, xylene, and chlorobenzene.

258. The method of claim **257**, wherein the first solvent is toluene and the second solvent is chloroform.

259. The method of claim **244**, wherein the first mixture comprises a third solvent.

260. A system for fabricating a photovoltaic device, comprising:

a source of a first substrate layer, having a first conductive surface;

a conveyor system for conveying the first substrate layer;

a source of a photoactive matrix fluidly coupled to a layer deposition system, the layer deposition system being at least partially disposed over the substrate conveyor system, to provide a layer of photoactive matrix on the first substrate layer; and

a source of a second conductive material coupled to the layer deposition system positioned over the substrate conveyor system for depositing a layer of the second conductive material onto a layer of photoactive matrix deposited on the first substrate layer.

261. The system of claim **260**, wherein the source of first substrate material comprises a rolled sheet of first substrate material.

262. The system of claim **260**, wherein the source of first substrate material further comprises a source of first conductive material and a deposition system for depositing the first conductive material onto the first substrate material to provide the first conductive surface.

263. The system of claim **260**, wherein the layer deposition system is selected from a doctor-blade, a screen printing system, an ink-jet printing system, a dip coating system, a sheer coating system, a tape casting system, and a film casting system.

264. A system for fabricating a layered device comprising a first population of nanostructures and a second population of nanostructures, which first population comprises nanostructures comprising a first material, and which second population comprises nanostructures comprising a second material different from the first material, the system comprising:

a source of a first substrate layer;

a conveyor system for conveying the first substrate layer; and,

a source of a composition comprising the first and second populations of nanostructures, fluidly coupled to a layer deposition system, the layer deposition system being at least partially disposed over the substrate conveyor system, to provide a layer in which the nanostructures of the first and second populations are intermixed on the first substrate layer.

265. The system of claim **260**, wherein the nanostructures comprise nanocrystals.

266. The system of claim **260**, wherein the nanostructures comprise nanowires.

267. The system of claim **260**, wherein the nanostructures comprise: a single-crystal nanostructure, a double-crystal nanostructure, a polycrystalline nanostructure, or an amorphous nanostructure.

268. The system of claim **260**, wherein the first material is a first inorganic material and the second material is a second inorganic material.

269. The system of claim **260**, wherein the first substrate layer has a first conductive surface.

270. The system of claim **260**, further comprising a source of a second conductive material coupled to the layer deposition system positioned over the substrate conveyor system for depositing a layer of the second conductive material onto the layer of intermixed nanostructures deposited on the first substrate layer.

271. The system of claim **260**, wherein the source of first substrate material comprises a rolled sheet of first substrate material.

272. The system of claim **260**, wherein the source of first substrate material further comprises a source of first conductive material and a deposition system for depositing the first conductive material onto the first substrate material to provide a first conductive surface.

273. The system of claim **260**, wherein the layer deposition system is selected from a doctor-blade, a screen printing system, an ink-jet printing system, a dip coating system, a sheer coating system, a tape casting system, and a film casting system.

274. A system for fabricating a layered device comprising a first population of nanostructures and a second population of nanostructures, which first population comprises nanostructures comprising a first material, and which second population comprises nanostructures comprising a second material different from the first material, the system comprising:

a source of a first substrate layer;

a conveyor system for conveying the first substrate layer;

a source of a first composition comprising the first population of nanostructures fluidly coupled to a layer deposition system, the layer deposition system being at least partially disposed over the substrate conveyor system, to provide a first layer; and,

a source of a second composition comprising the second population of nanostructures fluidly coupled to the layer deposition system, the layer deposition system being at least partially disposed over the substrate conveyor system, to provide a second layer.

275. The system of claim **274**, wherein the nanostructures comprise nanocrystals.

276. The system of claim **274**, wherein the nanostructures comprise nanowires.

277. The system of claim **274**, wherein the nanostructures comprise: a single-crystal nanostructure, a double-crystal nanostructure, a polycrystalline nanostructure, or an amorphous nanostructure.

278. The system of claim **274**, wherein the first material is a first inorganic material and the second material is a second inorganic material.

279. The system of claim **274**, wherein the first substrate layer has a first conductive surface.

280. The system of claim **274**, further comprising a source of a second conductive material coupled to the layer deposition system positioned over the substrate conveyor system for depositing a layer of the second conductive material onto the first or second layer.

281. The system of claim **274**, wherein the source of first substrate material comprises a rolled sheet of first substrate material.

282. The system of claim **274**, wherein the source of first substrate material further comprises a source of first conductive material and a deposition system for depositing the first conductive material onto the first substrate material to provide a first conductive surface.

283. The system of claim **274**, wherein the layer deposition system is selected from a doctor-blade, a screen printing system, an ink-jet printing system, a dip coating system, a sheer coating system, a tape casting system, and a film casting system.

284. A system for fabricating a nanocomposite layer, comprising:

a source of a composition comprising a population of nanostructures, a polymer and/or a small molecule, a first solvent, and a second solvent, wherein the first solvent has a vapor pressure that is not equal to a vapor pressure of the second solvent, and wherein at least one of the first and second solvents is free of chloroform and pyridine; and,

a layer deposition system fluidly coupled to the source of the composition, the layer deposition system being configured to deposit the composition on a substrate to provide the nanocomposite layer.

285. The system of claim **284**, wherein the layer deposition system is selected from a doctor-blade, a screen printing system, an ink-jet printing system, a dip coating system, a sheer coating system, a tape casting system, and a film casting system.